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Analysis of predictors for the implementation of residential photovoltaic solar systems in Vale do Paraíba

Análise de preditores para adoção de sistemas solares fotovoltaicos residenciais no Vale do Paraíba

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ABSTRACT: Photovoltaic energy is one of the main energy sources for the transition from non-renewable to renewable energy generation. However, in Vale do Paraíba (São Paulo, Brazil), despite the favorable conditions for implementing distributed generation of photovoltaic energy, the installed capacity is much lower than the existing generation potential, showing the factors that hinder a more substantial implementation and diffusion of this technology. Therefore, the focus of this study is to identify predictors that indicate the intention to apply photovoltaic solar systems in Vale do Paraíba. The information was collected through an online questionnaire (n = 168). The data collected are related to socioeconomic characterization, indicators of conscious consumption, subjective and objective knowledge, and perception. The results indicate the respondents' belief that it is expensive to install photovoltaic panels. However, they also believe that the investment is worthwhile. Furthermore, dependence on subjective and objective knowledge was observed ($p < 0.05$), indicating that those who claimed to know the solar photovoltaic system by distributed generation performed better when answering technical questions about the technology. Finally, gender, age group and perception are associated with the intention to apply photovoltaic panels.

Keywords: distributed generation; human behavior; conscious consumption; sustainability.

RESUMO: A energia fotovoltaica foi identificada como uma das principais fontes de energia na transição da geração de eletricidade de fontes não renováveis para fontes renováveis. No Vale do Paraíba (São Paulo, Brasil), apesar das condições favoráveis à implantação da geração distribuída de energia fotovoltaica, a capacidade instalada é muito inferior ao potencial de geração existente, evidenciando a presença de fatores que dificultam a maior adoção e difusão dessa tecnologia. Sendo assim, este trabalho teve como objetivo identificar preditores responsáveis pela intenção de adoção sistemas solares fotovoltaicos no Vale do Paraíba. As informações foram coletadas através de um questionário online (n = 168). Os dados coletados são referentes à caracterização socioeconômica, indicadores de consumo consciente, conhecimento declarado e efetivo e percepção. Como resultado, verificou-se que os entrevistados acreditam que a instalação de placas fotovoltaicas exige um elevado custo, no entanto, acreditam também que o investimento é válido. Foi observada dependência de conhecimento declarado e efetivo (p<0,05), indicando que pessoas que declararam conhecer o sistema solar fotovoltaico por geração distribuída tiveram melhor desempenho ao responder perguntas técnicas sobre a tecnologia. Por fim, gênero, faixa etária e percepção estão associados com a intenção de adoção de placas fotovoltaicas.

Palavras-chave: geração distribuída; comportamento humano; consumo consciente; sustentabilidade.

1. Introduction

The Sun is the main source of renewable energy. It sends radiant energy to Earth, which in turn produces several effects in the atmosphere. These effects are quite significant for the supply of energy resources such as wind energy, biomass energy and ocean wave energy. In this context, Brazil occupies a privileged area that receives around 1000 MWh of solar energy throughout the year (Silveira *et al.*, 2013).

The Brazilian electricity matrix is largely composed of renewable energy sources, with 64% of all electricity generated from hydroelectric plants (EPE, 2020). These plants are spread across the country and the generated electricity is distributed through an interconnected grid operated under centralized management (Martelli *et al.*, 2020). The disadvantages in this integrated system are related to potential interruptions during droughts and losses along the transmission line (Silva *et al.*, 2016). If there are interruptions, thermoelectric plants can be activated to contribute by generating energy, increasing the emission of greenhouse gases (Martelli *et al.*, 2020).

As most traditional sources of electricity production include the depletion of natural resources, governments are encouraging renewable energy sources as a greener way to produce electricity (De Groote *et al.*, 2016). Within this context, electrical systems are undergoing significant transformations in response to climate change policies.

The last 10 years showed a reduction in the electricity share from hydroelectric plants in Brazil's energy matrix (IEA, 2021). Consequently, demand has been met mainly by non-renewable sources (such as coal, natural gas and nuclear) (EPE, 2020; IEA, 2021). Despite the increasing consumption of non-renewable sources, there was an increase in the generation of wind and solar energy, mainly in the last 5 years (IEA, 2021). However, generating electricity by photovoltaic panels still represents a small share in the Brazilian energy panorama (1.1%), which represents 1.5% (2,473 MW) of the installed capacity (EPE, 2020).

Solar energy is considered a promising way to mitigate climate change and solve pollution problems (Irfan *et al.*, 2021a). According to Silva *et al.* (2016), the low exploitation of solar energy in Brazil is due not only to high costs, but also to current energy policies and the lack of government incentives to increase the production scale of photovoltaic panels.

In 2012, the National Electric Energy Agency (ANEEL) established rules for electricity production by end users through Resolution no. 482.

This Resolution defines the distributed generation modality, which allows the energy generated not consumed by the generator to be destined to the electricity grid, thus, the generator is in possession of an "energy credit" that cannot be reversed in cash, but it can be used to reduce consumer unit consumption in subsequent months (ANEEL, 2014).

The strong growth in the share of photovoltaic energy in the national matrix over the last 5 years includes concentrated and distributed generation, with 25% of total solar energy coming from distributed generation (Martelli *et al.*, 2020).

According to Rigo *et al.* (2019), when electricity generation modality is distributed on a small scale, the acquisition of photovoltaic systems is done by individuals with different levels of technical knowledge.

Social acceptance is defined as a positive attitude towards a particular technology or measure, which is crucial for its successful introduction into society (Huijts *et al.*, 2012). Human choice is a critical and controlling factor in energy use, which is influenced by various contextual and personal circumstances. In recent years, there have been several studies devoted to social perceptions around the acceptance of residential solar photovoltaic systems (Vasseur & Kemp, 2015; De Groote *et al.*, 2016; Parkins *et al.*, 2018; Garlet *et al.*, 2019; Rathore *et al.*, 2019; Alrashoud & Tokimatsu, 2020; Lau *et al.*, 2020; Balta-Ozkan *et al.*, 2021; Irfan *et al.*, 2021a; 2021b). Alipour *et al.* (2020) found that implementing photovoltaic solar energy relies on individual predictors (such as personality, values, attitude and risk perception), social (such as education, age, gender and income) and information predictors (such as financial and technical knowledge). According to Parkins *et al.* (2018), the factors that affect adopting photovoltaic solar energy can be classified into: knowledge, environmental values and attitudes, engagement, seeing and experiencing renewable energy infrastructure and government regulations. Therefore, implementing photovoltaic systems may vary depending on the country and region of the country analyzed (Balta-Ozkan *et al.*, 2021).

There has been a scientific effort to try to understand and designate significant predictors, model the behavior of families and predict the rate of diffusion, putting into practice a wide range of approaches (Alipour *et al.*, 2021). In studies carried out in developed countries, implementing residential photovoltaic solar panels has depended on information about the interviewed population, neighborhood effect or number of pre-existing installations and environmental values (Parkins *et al.*, 2018; Balta-Ozkan *et al.*, 2021); while in emerging economies, the predictors mostly fall on knowledge, awareness, trust and investment (Rathore *et al.*, 2019; Alipour *et al.*, 2020).

Due to Brazil's territorial extension and social inequality, studies on the intention of adopting photovoltaic panels in the national territory may require a substantial number of respondents in the country's different regions. Some studies have already been carried out in specific regions, like the study carried out by Garlet *et al.* (2019) in the southern region, where the major concerns were durability and quality of photovoltaic systems, initial investment, consumer culture and the lack of adequate knowledge about photovoltaic technology.

Therefore, the transition to energy based on renewable resources faces a series of sociocultural challenges related to the acceptance of changes and the adoption of new technologies (Garlet *et al.*, 2019).

An important tool to encourage applying policies is data on the intention to adopt distributed generation photovoltaic solar systems. In addition, solar power generation systems can improve the quality of life of residents as a result of reduced carbon emissions; generation of local employment opportunities; benefits to the national economy and economic return (Irfan *et al.*, 2021a). At a global level, implementing clean energy is in line with the sustainable development goals (SDGs) of the United Nations 2030 Agenda (UN, 2017).

Therefore, the objective of this research was to analyze the influence of social and individual predictors, and information for installing residential solar photovoltaic systems in the Vale do Paraíba of São Paulo.

2. Materials and methods

2.1. Study area

The study area is located in the São Paulo portion of the Paraíba do Sul river basin, one of the most developed regions in Brazil. The total urban population of the study area is estimated at 2,576,250 people (IBGE, 2020).

The name of the region is because the Paraíba do Sul River and its basin has a drainage area of about 55,500 km², of which 13,900 km² are located in the state of São Paulo (ANA, 2021).

In the region, the energy generation largely comes from hydroelectric plants, thus, part of the main tributaries of the Paraíba do Sul River were intercepted, and in the São Paulo portion of the hydrographic basin under study, there are three hydroelectric plants: Paraibuna (Paraibuna/Paraitinga), Santa Branca (Paraíba do Sul river) and Jaguari (Jaguari river).

2.2. Conceptual model and hypotheses

Decision Making Behavioral Model was used as a tool to study the predictors for adopting photovoltaic solar systems. This model describes the implementation behavior and identifies significant predictors (Wilson & Dowlatabadi, 2007). The predictors were grouped according to their characteristics based on the theory of the Rational Action Approach (Alipour *et al.*, 2021).

The information collection for analysis was performed using primary data in order to better understand the included predictors. Furthermore, the primary data allows to analyze the attitudes, personality traits, perceived risks, motives and personal and environmental values of individuals. Therefore, a questionnaire was developed for data collection in order to analyze the influence of social, individual and information predictors. The predictors were selected according to the list available in the literature review carried out by Alipour *et al.* (2020). Table 1 describes the classification of predictors and the respective indicator used for analysis in this study.

For each predictor, indicators that make it possible to represent the analyzed predictor can be selected. For social predictors, the indicators used refer to demographic characteristics. For individual and information characteristics, the predictors are usually subjective and the indicator used is different.

TABLE 1 – Classification of selected predictors and indicators used.

Characteristic	Category	Subcategory	Predictor	Indicator
Social	Age and gender	Age	Age	Age
		Gender	Gender	Gender
	Culture		Social Class	Socioeconomic classification
	House features	Non-physical features	Geographic region	Geographic location (municipality)
Individual (endogenous)	Personality		Habits and routine, conscience	Conscious consumption indicators
	Values, stereotypes	Environmental values	Attitude and environmental behavior	
	General attitudes	Motives	Motivation for implementation, belief	Affirmations (analysis of perception and purchase intention)
Information	Common knowledge		Knowledge of solar photovoltaic systems	Self-declaration (declared and effective knowledge)

SOURCE: Adapted from Alipour et al. (2020).

2.2.1. Social predictors

Social predictors can be classified into 10 categories: education, age and gender, income, socioeconomic, ethnicity, culture, family structure, sociopolitical, household and general characteristics (Alipour *et al.*, 2020). The criteria of age and gender, culture and characteristics of the house were selected based on this list. The indicators (Table 1) were selected based on the ease of access, understanding the information requested by the respondents and the widespread use of the socioeconomic classification.

The use of these indicators is based on the hypothesis that age, gender and socioeconomic status can influence the intention to adopt solar photovoltaic systems.

2.2.2. Individual predictors

Individual predictors can be categorized as personality, values and stereotypes, attitudes towards financial and technical aspects, general attitudes and perceived risk (Alipour *et al.*, 2020). In this context, values can play an important role in the consumer's decision process, with regard to product and brand choice (Chen, 2014). Thus, value is related to consumer attitudes towards issues involving a specific purchase. These values can be related to the environment and personal issues. The evaluation of these values is through environmental behavior and attitude. In this context, it highlights the concept of conscious consumption, which is related to shopping habits and the impacts of human actions on natural resources (CNDL & SPC, 2019). These habits can be evaluated through conscious consumption indicators (CCI). Therefore, 5 ICC were selected, which have a direct relationship with electric energy consumption.

Individual predictors may exhibit an immediate action effect, such as readiness to apply, purchase, as well as acceptance. In these cases, the predictor is evaluated based on statements or open questions. This information is important to compare the analysis of more subjective predictors with the individual's perception of technology when answering the questionnaire. Therefore, an analysis of the individuals' perception regarding the benefits and intention to apply the technology was also used.

These indicators are used based on the hypothesis that conscious consumption habits and attitudes can influence the intention to implement solar photovoltaic systems.

2.2.3. Information predictors

Information predictors can be categorized as financial, technical, common knowledge and information channels (Alipour *et al.*, 2021). As most studies on individuals' perception about applying photovoltaic solar systems are carried out in countries where this technology is more widespread, they use predictors of financial knowledge, such as economic benefits, purchase and rent prices. As in the studied region the technology is not widespread, it was assumed it is also little known. In this context, we evaluated the individuals' common knowledge based on the concept of declared and effective knowledge. It was then assumed that individuals with greater effective knowledge about photovoltaic solar systems have a positive attitude towards implementing this technology.

2.3. Questionnaire structure and sampling

All questionnaire questions were standardized with answers in a closed format. The questionnaire items were used to measure the social, individual and information predictors of the photovoltaic system. The questionnaire was prepared in Portuguese with 4 sections and a pre-section, as follows:

(i) Pre-section: brief research presentation, information about average time used to answer the questionnaire and screening to access the questionnaire. The respondent should declare he resides in Vale do Paraíba of São Paulo to access the first section of the questionnaire;

(ii) Section 1: questions related to the respondents' sociodemographic information (social predictors). This section aimed to build a profile of the respondent with questions related to location of the residence, age group, gender, socioeconomic classification (ABEP, 2018);

(iii) Section 2: series of information related to the habits practiced (individual predictors) based on the concept of conscious consumption adapted from CNDL and SPC (2019). The degree of agreement with the information was performed using the five-point Likert scale;

(iv) Section 3: series of questions and statements to evaluate the participant's declared knowledge about solar photovoltaic systems (information predictors), where the respondent declared or not to have knowledge about electricity generation. Effective knowledge was computed from a series of true or false statements;

(v) Section 4: series of statements aimed at evaluating the respondent's perception, based on the advantages of use, future projection and intention to implement this form of energy generation in their homes (individual predictors). A five-point Likert scale was used.

The data were collected between March and May 2020 through an online questionnaire, available in Portuguese and distributed on social networking services. Respondents were instructed to divulge the questionnaire. Therefore, the non-probabilistic snowball sampling technique was used, which the interviewees used to recruit individuals among their acquaintances. A total of 168 participants responded to the questionnaire. There were no restrictions for respondents regarding type of house, residential area, income or type of work.

2.4. Data analysis

The data were analyzed descriptively. Hypothesis tests were performed using Fisher's method ($p < 0.05$). All analyzes were performed using RStudio software (version 1.3.959) and Microsoft Excel.

3. Result and discussion

3.1. Demographic characteristics

The demographic characteristics (Table 2) of the interviewees showed that most people live in the cities of São José dos Campos (42.3%) and Lorena (32.1%). In terms of gender, female participation corresponded to 51.8%, while male respondents represented 48.2%. Most respondents declared to be between 18 and 24 years old (28.6%) and 25 to 34 years old (31.0%). Regarding socioeconomic level, 60.1% of the sample corresponds to the highest socioeconomic level (class "A"). Notwithstanding the high number of people interviewed are from class A, the distribution of class "A" in Brazil is estimated at only 2.8% (ABEP, 2018). The high representation of young people in studies using online questionnaires was also evidenced by Alrashoud and Tokimatsu (2020), who attributed this fact to young people using the internet for longer periods of time, mainly via smartphones.

TABLE 2 – Demographic characteristics of respondents (n=168).

Category	**Percentage of responses (%)**
Gender	
Masculine	48.2
Feminine	51.8
Age group	
18 to 24	28.6
25 to 34	31.0
35 to 44	6.5
45 to 54	12.5
55 to 64	17.9
Over 65	3.6
Social class	
A	60.1
B-1	18.5
B-2	16.7
C-1	3.6
C-2	1.2
Municipality of residence	
São José dos Campos	42.3
Lorena	32.1
Caçapava	6.0
Jacareí	6.0
Cruzeiro	3.0
Pindamonhangaba	3.0
Guaratinguetá	2.4
Taubaté	2.4
Other	3.0

SOURCE: Research data.

3.2. Conscious consumption indicators

Analyzing the degree of agreement of the participants with 5 statements related to the ICC (Table 3) it was found that most individuals agree with the initiatives described in the statements. Not leaving the light on in unoccupied environments was the one with the highest rate of agreement, demonstrating that the interviewees are concerned with electricity consumption. This concern may be related to financial or environmental motivations or both. According to Wolske *et al.* (2017), applying photovoltaic solar systems involves greater financial commitment, so in many studies there is no evidence that shows the extent of influence of pro-environmental behaviors on low financial investment.

The consumption of household appliances with energy efficiency seals was the second action with the highest rate of agreement. This action is related to the use of appliances with a higher investment value, however, their use can bring long-term economic and environmental benefits. In addition, people who use clean energy are more engaged with environmental issues than the rest of the population (Ek, 2005; Hansla *et al.*, 2008).

An individual's concern with environmental issues can be an important conscious consumption predictor (Adnan & Shahrina, 2021). Some studies have reported that consumers' environmental concerns affect the purchasing behavior of environmentally friendly goods (Roberts & Bacon, 1997; Adnan & Shahrina, 2021).

3.3. Declared and effective knowledge

The analysis of declared knowledge (Table 4) was carried out through the respondent's self-declaration on his/her knowledge about photovoltaic systems by distributed generation. In addition to the "Yes" and "No" options, the respondent could also choose the option "I don't know how to answer." Of the total of valid answers, twenty-eight participants (16.6%) declared not knowing how to answer the question. The responses of people who chose this option were excluded from the statistical analyses in order to test the relationship between declared and actual knowledge only of those who actually made a statement, choosing between "Yes" and "No". The sample was then reduced to 140 valid answers, in which 50% of the participants declared to know about solar energy by distributed generation. Among these participants, only 5.7% answered all five questions correctly, based on identifying this technology through images (three questions) and true or false statements regarding its application (two questions).

In a study carried out in Indonesia, respondents were asked to rate their knowledge of photovoltaic panel technology using the 5-point Likert scale. Most participants reported their knowledge evaluated as competent (Setyawati, 2020). However, self-assessment can lead to overestimation if it is not confronted with matters that include evaluating the respondents' technical and financial knowledge.

TABLE 3 – Relative frequency (%) of each degree of agreement for conscious consumption indicators, considering the total number of participants.

Conscious consumption actions	**Relative frequency (%)**				
	1	**2**	**3**	**4**	**5**
Avoid leaving lights on in unoccupied environments.	0.6	0.6	2.4	19.6	76.8
Turn off electronic devices when they are not in use.	4.8	5.4	13.7	31.0	45.2
Wait for the food to cool before storing it in the fridge.	14.3	10.1	14.3	20.8	40.5
Uses appliances with the energy efficiency seal.	4.2	6.0	16.1	23.2	50.6
Decrease water usage.	0.6	6.5	14.9	32.7	45.2
Wait for the food to cool before storing it in the fridge.	4.8	5.4	13.7	31.0	45.2

SOURCE: Research data.

Note: 1 - Strongly disagree, 2 - Partially disagree, 3 - Neither agree nor disagree, 4 - Partially agree, 5 - Strongly agree.

In this study, there was a low percentage related to effective and declared knowledge, which may be linked to concepts and vocabularies that are not widely disseminated in the country. The term "distributed generation" can cause uncertainty even among those who know how photovoltaic panels work. In addition, there is some confusion between solar heaters and photovoltaic panels. Among the participants who declared to know about distributed generation, 44.3% mistakenly classified the image of a solar heater as an installation of photovoltaic solar panels.

The Fisher test was performed to determine the relationship between the participants' declared and tested effective knowledge, considering the independence between these variables as the null hypothesis. The descriptive level, or, the p-value found was much lower than the significance level of 0.05 used (less than 0.1%) and, therefore, the null hypothesis of independence between the variables was rejected. Thus, we accept the hypothesis that there is a dependency relationship between the variables declared knowledge and effective knowledge. Therefore, the participants who claimed to know about solar energy by distributed generation presented greater performance compared to participants who acknowledged not knowing this technology.

TABLE 4 – Relationship between the participant's declared knowledge and correct answers.

Number of correct answers	**Did the participant claim to know solar energy by distributed generation?**		**Total**
	No	**Yes**	
No correct answers	30	2	32
1 correct answer	15	11	26
2 correct answers	14	17	31
3 correct answers	7	29	36
4 correct answers	4	7	11
5 correct answers	0	4	4
Total	70	70	140

SOURCE: Research data.

3.4. Analysis of perception and purchase intention

The respondents' perception was analyzed based on the degree of agreement expressed by the respondent in relation to 6 statements (Table 5).

The affirmation that showed the highest level of agreement and the lowest standard deviation referred to the environmental benefits associated with this type of technology (“Photovoltaic solar energy contributes to the sustainable development of society”). The second alternative that the participants most agreed with also referred to the environmental benefits (“Photovoltaic solar energy contributes to reducing the effects of greenhouse gases”). According to Parkins *et al.* (2018) better informed consumers are more likely to understand the environmental concerns associated with electricity generation systems and are more likely to appreciate the environmental benefits of investing in alternative renewable energy systems.

Regarding the financial aspects associated with the systems, the participants showed a lower level of agreement with the variable that stated that photovoltaic panels required high installation costs and, therefore, would not bring a positive return on investment (“Photovoltaic solar energy requires high installation costs and is NOT WORTH the investment”). Together with the high level of agreement of the following question, which addresses the same topic, but which refers to investment as something beneficial to the consumer (“Photovoltaic solar energy requires high installation costs, but is WORTH the investment”), it is clear that most participants affirm these installations require high costs, but have the perception that the investment would bring more future benefits than losses. In a study carried out in Saudi Arabia, the vast majority of respondents recognize the potential causes and effects of global warming and believe that expanding the use of solar energy could be beneficial to face this challenge, however, most respondents resisted paying a $2.5 increase to mitigate this problem (Alrashoud & Tokimatsu, 2020).

TABLE 5 – Means and standard deviations for the statements included in the perception questionnaire, considering the total number of participants.

Affirmations	Weighted average	Standard deviation
Photovoltaic solar energy contributes to the sustainable development of society.	4.75	0.554
Photovoltaic solar energy contributes to reducing the effects of greenhouse gases.	4.42	0.896
Photovoltaic solar energy is the future of electric power generation.	4.29	0.774
Photovoltaic solar energy requires high installation costs and is NOT WORTH the investment.	2.35	1.097
Photovoltaic solar energy requires high installation cost, but is WORTH the investment.	4.05	0.947
I intend to one day install photovoltaic solar panels on my property.	4.25	0.943

SOURCE: Research data.

Note: the average scores were calculated using a five-point Likert scale.

The participants also showed a high rate of agreement with the statement that dealt with the individual's intention to own this electricity generation system (“I intend to one day install photovoltaic solar panels on my property”).

Residential photovoltaic systems often require a family’s significant initial investment (Burnett & Hefner, 2021). In some countries, these systems qualify for various discounts, tax credits, and other incentives that can significantly reduce initial costs (Rathore *et al.*, 2019; Bunea *et al.*, 2020; Burnett & Hefner, 2021). In Brazil, the incentives to adhere to these systems are due to the very high energy tariffs, thus some consumers adhering the distributed generation (Luna *et al.*, 2019) and; the publication of Decree 61,439/2015 (São Paulo, 2014), which exempts the energy generated from solar photovoltaic systems from taxes in the State of São Paulo. However, the incentives from public policies can be better, such as those observed in European countries, which have regulatory norms (tax exemptions, subsidies and acquisition fees) (Pinto *et al.*, 2016).

3.5. Predictors for implementing photovoltaic solar systems

All questionnaire questions were submitted to Fisher's test in RStudio, and those with a p-value lower than 0.05 were classified as dependent on the intention to implement.

The analysis of socioeconomic variables, gender (p-value = 0.0118), age (p-value = 0.0007) and city (p-value = 0.0031) show it was statistically significant. Male participants aged between 18 and 34 years old showed higher intention to implement residential solar photovoltaic systems, while most people who declared not being interested are between 45 and 64 years old. Research has shown that certain family characteristics, such as age and education, have an impact on implementing photovoltaic systems. (Vasseur & Kemp, 2015; De Groote *et al.*, 2016).

Based on the analysis of the CCI, it was found that only the affirmation “Turn off electronic devices when they are not being used” (p-value = 0.0145) is associated with the intention to implement, so that people who do not declare an intention to implement, are also those that showed a lower rate of agreement with this affirmation. According to Chen (2014), values related to environmental concerns actually have a positive impact on people's lifestyles, especially when it comes to the intention to implement solar systems. In a study carried out with owners of solar systems, it was found that the motivation for implementing the system was related to the reduction of environmental impacts (Horne *et al.*, 2021). However, motivation was reported in open-ended questions, and respondents reported their environmental motivation.

Most potential consumers show a higher level of agreement with the benefits of solar energy. In the perception analysis, people who agreed with the affirmations “Photovoltaic solar energy contributes to the sustainable development of society” (p-value = 0.0000), “Photovoltaic solar energy contributes to reducing the effects of greenhouse gases” (p-value = 0.0000), “Photovoltaic solar energy contributes to reducing the effects of greenhouse gases” (p -value

= 0.0001), “Photovoltaic solar energy is the future of electric power generation” (p-value = 0.0000) and “Photovoltaic solar energy requires high installation costs, but WORTH the investment” (p-value = 0.0000) showed greater intention to implement residential solar photovoltaic systems. People who feel morally obliged to face climate change already believe that solar energy can be beneficial (Wolske *et al.*, 2017). Furthermore, individuals who believe that solar energy is financially and environmentally beneficial are more likely to be interested in and purchase a residential solar photovoltaic system (Horne *et al.*, 2021).

There is no evidence that effectively manifested knowledge positively influenced the participants' intention to implement. In addition, no analyses were found in the literature regarding the influence of effective and declared knowledge on implementing photovoltaic panels. Few studies analyze knowledge on social influence in relation to the adoption of photovoltaic solar energy (Lau *et al.*, 2020). In a study carried out in Malaysia, it was found that price, knowledge, favorable conditions and social influence are the only four factors that significantly influence the behavioral intention to use a technology (Lau *et al.*, 2020). However, the economic value of technology had a greater positive effect on social influence compared to knowledge (Lau *et al.*, 2020). According to Parkins *et al.*, (2018), the factual knowledge of energy systems does not indicate the intention to implement photovoltaic technology. Perceived knowledge of the energy system, in other words, confidence about what it is and what it represents to a person, rather than the science behind it, predicts intentions to implement (Parkins *et al.*, 2018). In addition, implementing photovoltaic technology is also associated with costs, government incentives (subsidies), low maintenance and efficiency (Rathore *et al.*, 2019; Bunea *et al.*, 2020; Alipour *et al.*, 2021), which must be taken into consideration in future research. Another aspect identified in recent studies is the failure to consider alternative microtechnologies in the family’s decision to choose (Rathore *et al.*, 2019; Bunea *et al.*, 2020).

David *et al.* (2021) found that the most relevant aspects to implement residential photovoltaic systems in Brazil are: lack of knowledge on the subject, lack of priority, cultural, lack of influencers and costs. In addition, implementing photovoltaic solar energy in Brazil has been motivated not only by the diversification of the energy matrix, but also by the needs, problems and barriers that the Brazilian energy sector has faced in recent years (Papageorgiou *et al.*, 2020).

The lack of studies that analyze the same variables complicates the comparison with the data obtained in this research. Approaches such as the neighborhood effect and trust can be interesting, however, few residences located in Vale do Paraíba have photovoltaic panels on their roofs, which limits the use of this indicator. In addition, it can be difficult to measure the trust aspect, since the effective knowledge of the people evaluated showed that many still do not know how to differentiate photovoltaic panels from solar heaters. To stimulate development, it is necessary to have public incentive policies that focus not only on financial aspects, such as tariffs exemptions, but also on the dissemination of information about this technology.

4. Conclusion

This study explored public opinions about implementing solar photovoltaic systems in Vale do Paraíba. Specific focus was given to social predictors (demographic characteristics), individual predictors (indicators of conscious consumption, perception and purchase intention) and knowledge (actual and declared knowledge). Therefore, it is concluded that:

• the social predictors of gender, age and geographic location influence the intention to implement photovoltaic technology;

• the individual predictors analyzed through the ICC may reflect the intention to apply photovoltaic technology. People who turn off electronics that are not being used are more likely to implement this technology;

• the individual predictors analyzed through the individual perception of the benefits of solar energy indicate the intention to implement this type of energy;

• the predictor of individuals' common knowledge does not influence the intention to implement this technology. People who effectively know the technology are no longer likely to apply it.

Given the importance of predictors for the successful diffusion of this technology, it is recommended that additional studies be carried out to identify the factors that influence decision making. In addition, a study that includes individuals who own photovoltaic solar systems is also recommended to understand the motivations to implement this system. Finally, almost all respondents accepted the idea of installing solar photovoltaic systems in their homes. Most of these participants see solar energy as an alternative energy source, and it is recommended that more efforts be utilized to expand the use of renewable energy.

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